

TOP QUARK PHYSICS RESULTS FROM DØ

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For the DØ Collaboration

We describe recent measurements of the $t\bar{t}$ production cross section and the mass of the top quark from the DØ Collaboration.

1. Introduction

In this paper we describe some recent results on the production and properties of top quarks obtained by the DØ Collaboration at the Fermilab Tevatron Collider. New measurements of the top quark production cross section have been made using 45–107 pb⁻¹ of data collected at $\sqrt{s} = 1.96$ TeV. We also describe new measurements of the top quark mass using 125 pb⁻¹ of data collected at $\sqrt{s} = 1.8$ TeV.

2. Measurements of the $t\bar{t}$ Production Cross Section

Production of $t\bar{t}$ pairs at the Tevatron at $\sqrt{s} = 1.96$ TeV proceeds via quark-antiquark annihilation ($\approx 85\%$) and gluon-gluon fusion ($\approx 15\%$) and the theoretical prediction for the production cross section is 6.8 pb⁻¹ [1,2]. Comparisons of the prediction with experimental measurements are an important test of our understanding of the QCD production mechanisms. Because of the unusually high mass of the top quark, it has been suggested that the top quark may play a special role in symmetry breaking and that non-Standard-Model physics may show up as anomalies in top quark production and decay. Precise measurements of the $t\bar{t}$ cross section utilizing different top decay channels are therefore an important goal.

Recent measurements made by the DØ Collaboration include the dilepton decay channels ee , $\mu\mu$, and $e\mu$ and the lepton plus jets channels e +jets and μ +jets. The dilepton channels have small branching fractions but the signal is relatively free of background. Events are required to contain two charged leptons, significant missing transverse energy (\cancel{E}_T) consistent with

the decay $t \rightarrow Wb \rightarrow \ell\nu b$, and at least two jets. The results are summarized in Table 1.

Table 1. Event yields, estimated backgrounds, and expected numbers of signal events for the dilepton analyses.

	ee	$\mu\mu$	$e\mu$
Int. Luminosity (pb^{-1})	107	90.4	97.7
Background	0.6 ± 0.5	0.7 ± 0.4	0.6 ± 0.4
Expected signal	0.6 ± 0.1	0.5 ± 0.1	1.7 ± 0.3
Signal + bkgd	1.2 ± 0.5	1.2 ± 0.5	2.3 ± 0.5
Data	2	0	3

The lepton + jets channels have larger branching fractions but also much large backgrounds compared with the dilepton channels. Events are required to have a high- p_T electron or muon, significant missing E_T , and at least three or four jets, consistent with $t\bar{t} \rightarrow Wb Wb \rightarrow \ell\nu jjbb$. To further separate the signal from the W + jets background, the events are required to pass one of the following tagging algorithms:

Topological Tag ($\ell\nu + \geq 4$ jets, 92 pb^{-1}): Aplanarity $A > 0.065$, $H_T^{all} = p_T(W) + \sum_{jets} E_T > 180 \text{ GeV}$ ($e + \text{jets}$) or $> 220 \text{ GeV}$ ($\mu + \text{jets}$)

Soft Muon Tag ($\ell\nu + \geq 4$ jets, 92 pb^{-1}): $A > 0.004$, $H_T^{all} > 110 \text{ GeV}$, and a muon with $p_T > 4 \text{ GeV}$, $|\eta| < 2.0$ within $\Delta R < 0.5$ of a jet

Secondary Vertex Tag (SVT) ($\ell\nu + \geq 3$ jets, 45 pb^{-1}): Secondary vertex with transverse decay length satisfying $L_{xy}/\sigma(L_{xy}) > 5$

Charged Signed Impact Parameter Tag (CSIP) ($\ell\nu + \geq 3$ jets, 45 pb^{-1}): Two tracks with charge signed impact parameter significance > 3 ; or three tracks with CSIP significance > 2

Here we briefly discuss results from the SVT and CSIP tag analyses. The b -jet tagging efficiency as a function of jet p_T is shown in Fig. 1, where the measured efficiency (points) is compared to the expectation from Monte Carlo (line). The resulting distribution of number of jets per event for the two analyses after all event selection requirements is shown in Fig. 2. A clear excess of events in the signal region (≥ 3 jets) can be seen.

The cross section measurements obtained from the above analyses are shown in Fig 3. As can be seen, the measurements are consistent with

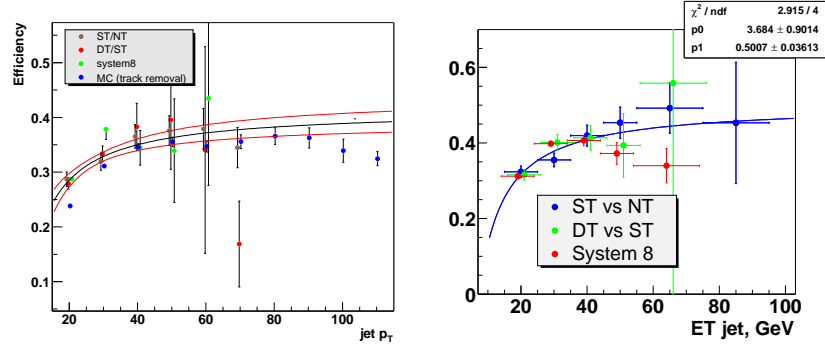


Figure 1. Efficiency for b-tagging as a function of jet p_T for the CSIP (left) and SVT (right) tagging algorithms.

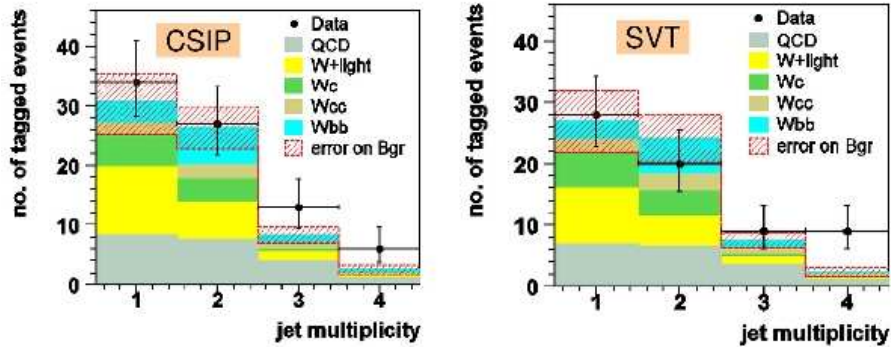


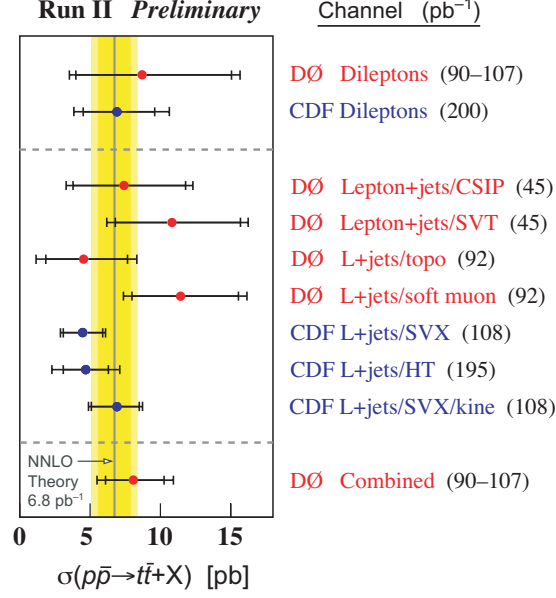
Figure 2. Distribution of the observed number of jets per event for the CSIP and SVT tagged samples.

the theoretical predictions. The combined $D\bar{O}$ cross section is $\sigma(t\bar{t}) = 8.1^{+2.2}_{-2.0} (\text{stat})^{+1.6}_{-1.4} (\text{syst}) \pm 0.8 (\text{lum}) \text{ pb}$.

3. Improved Measurement of the Top Quark Mass

A precise measurement of the top quark mass (M_t) is important because of the dependence of the electroweak precision observables on M_t . The prediction of the Higgs boson mass from fits to the electroweak data is particularly sensitive to M_t .

A new method based on event probability has been used to obtain an improved measurement of the top quark mass by $D\bar{O}$. The new method uses the Run I lepton + jets data selected by requiring an isolated electron

Figure 3. Measurements of the $t\bar{t}$ production cross section at $\sqrt{s} = 1.96$ TeV.

or muon with $E_T > 25$ GeV and pseudorapidity $|\eta^e| < 2.0$, $|\eta^\mu| < 1.7$, at least four jets with $E_T > 25$ GeV and $|\eta^{jet}| < 2.0$, $\cancel{E}_T > 20$ GeV, and requiring the W boson decay products to satisfy $E_T^{lep} + \cancel{E}_T > 60$ GeV, and $|\eta_W| < 2.0$.

A probability density is defined for each event, which uses all measured quantities from each reconstructed event:

$$P(x, M_t) = \frac{1}{\sigma(M_t)} \int d\sigma(y, M_t) dq_1 dq_2 f(q_1) f(q_2) W(y, x)$$

where $d\sigma(y, M_t)$ is the differential cross section calculated from the leading-order (LO) matrix element and phase space factor, $f(q_1), f(q_2)$ are the parton distribution functions, and $W(x, y)$ is the transfer function which relates partonic four-momenta ($y = (p_1, p_2, \dots, p_n)$) to the measured four-momenta x of the final state particles and jets. Because of the use of the LO matrix element, a further requirement that the selected events must contain exactly four jets is imposed. The ambiguity of the jet-parton correspondence is handled by summing over all twelve assignments of the four jets to the partons ($b\bar{b}q_3q_4$). This means that all combinations are used correctly, whereas in the previous mass measurement method [3] only the

solution with the best χ^2 was chosen. The total event probability is defined as

$$P(x; c_1, c_2, M_t) = c_1 P_{t\bar{t}}(x; M_t) + c_2 P_{bkgd}(x)$$

where c_1, c_2 are constants and P_{bkgd} is the probability density for background, defined using the LO matrix element for the $W + 4$ jets process. A likelihood function is formed using $P(x; c_1, c_2, M_t)$ which is then maximized to obtain M_t, c_1 and c_2 . An additional cut on the background probability $P_{bkgd} < 10^{-11}$ is applied to increase the signal purity, resulting in 22 events surviving the final cuts. The result for the fitted top quark mass is $M_t = 180.1 \pm 3.6$ (stat) ± 3.9 (syst) $= 180.1 \pm 5.3$ GeV/ c^2 . The improvement in statistical uncertainty compared with the previous result is equivalent to a factor of 2.4 more data. Using this new result in place of the previous DØ lepton + jets result gives a world average top quark mass of 178.0 ± 4.3 GeV/ c^2 and changes the best-fit Higgs mass from 96 GeV/ c^2 to approximately 125 GeV/ c^2 (see Fig. 4).

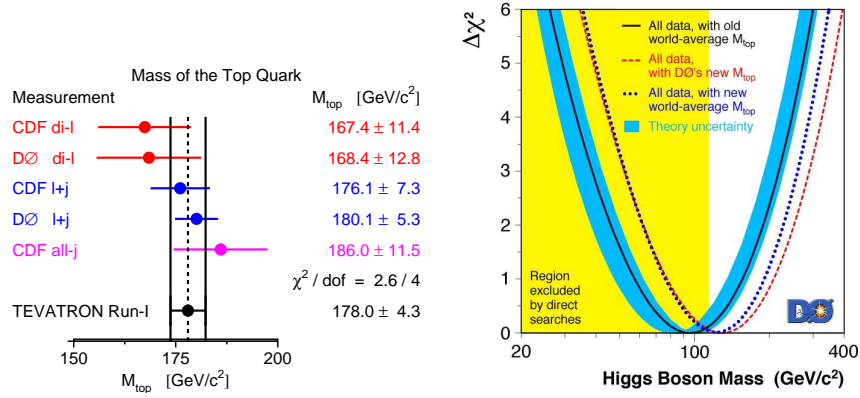


Figure 4. Measurements of the top quark mass (left) and $\Delta\chi^2$ vs. m_H from fits to the EW data (right).

References

1. N. Kidonakis and R. Vogt, *Phys. Rev.* **D68**, 114014 (2003).
2. M. Cacciari, S. Frixione, M.L. Mangano, P. Nason, and G. Ridolfi, hep-ph/0303085.
3. S. Abachi et al. (The DØ Collaboration), *Phys. Rev. Lett.* **79**, 1197 (1997).